



Software Defined Radio Developments and Verification for Space Environment on NASA's Communication Navigation, and Networking Testbed (CoNNeCT)

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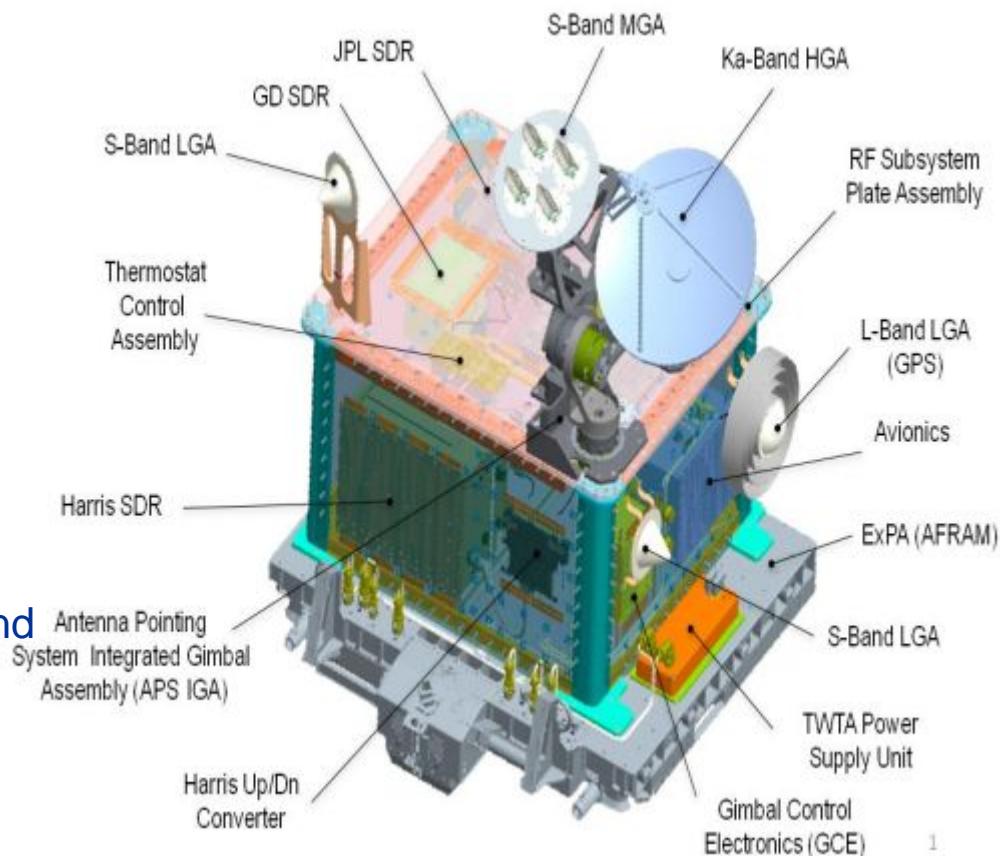
SCAN Testbed

Science & Technology Goals & Objectives

- **INVESTIGATE the APPLICATION of SDRS TO NASA MISSIONS**
 - Mission advantages and development/verification/operations aspects
 - On-Orbit Reconfiguration
 - More process intensive functions within the radio subsystem
- **SDR TECHNOLOGY DEVELOPMENT**
 - SDR Platforms to TRL-7
 - SDR platform hardware & waveform compliant to STRS, Foster Agency adoption
 - Understand/characterize space effects and SDR performance
- **VALIDATE FUTURE MISSION OPERATIONAL CAPABILITIES**
 - Capability representative of future missions
 - Comm data rate, performance, navigation/ GPS, networking/routing
 - Understand SDR performance (reliability, SEE, telemetry, instrumentation)
 - Multiple and simultaneous RF Links (Ka-band, S-band, L-band/GPS)
 - Experimenter sw applications (On-board networking , DTN, routing, and security applications)

Flight System Overview

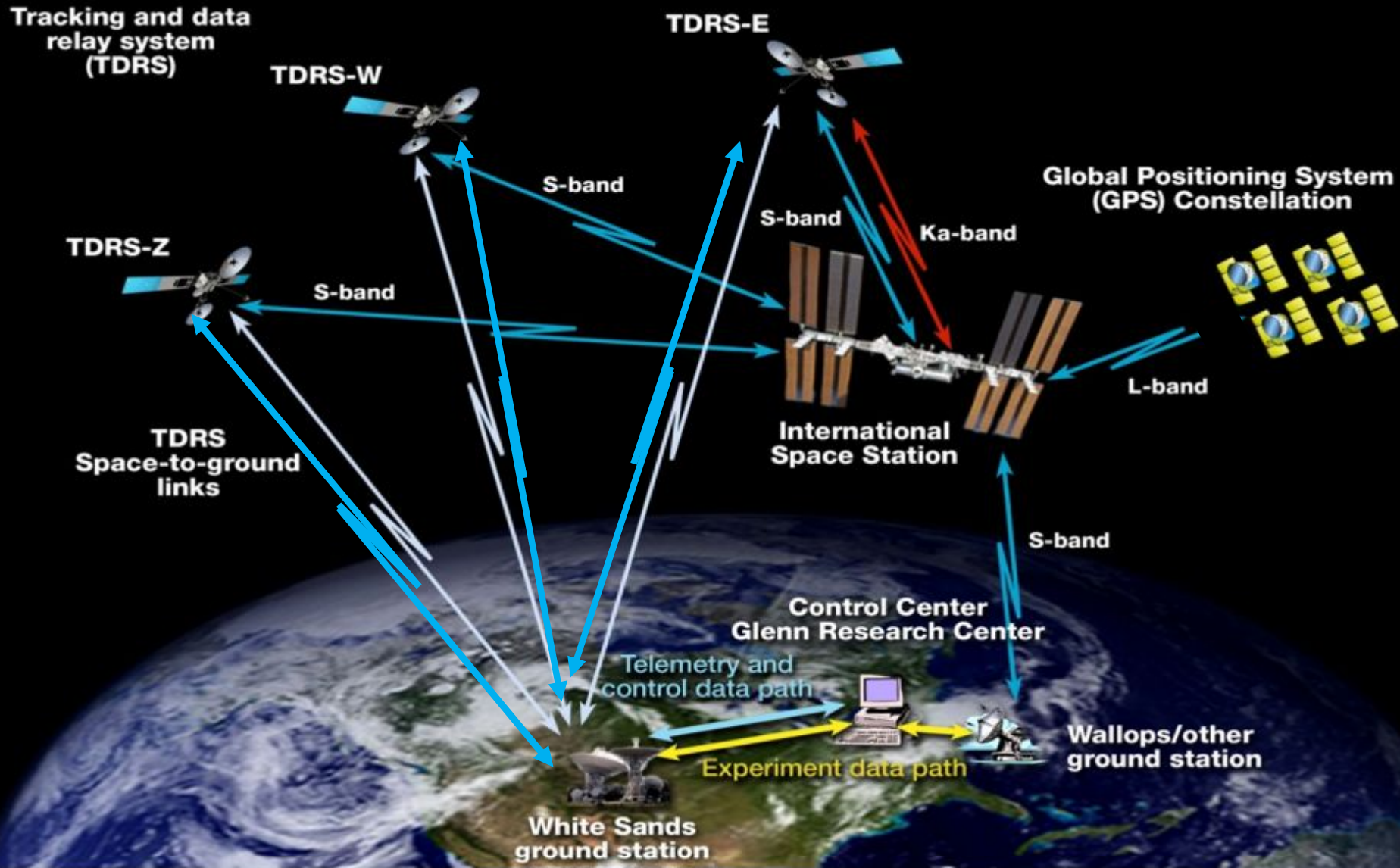
- Communication System
 - SDRs
 - 2 S-band SDRs (1 with GPS)
 - 1 Ka-band SDR
 - RF
 - Ka-band TWTA
 - S-band switch network
 - Antennas
 - 2 - low gain S-band antennas
 - 1 - L-band GPS antenna
 - Medium gain S-band and Ka-band antenna on antenna pointing subsystem.
 - Antenna pointing system.
 - Two gimbals
 - Control electronics
- Flight Computer/Avionics
- Flight enclosure provides for thermal control/radiator surface.



Total mass ~746 lb



SCAN Testbed System Architecture





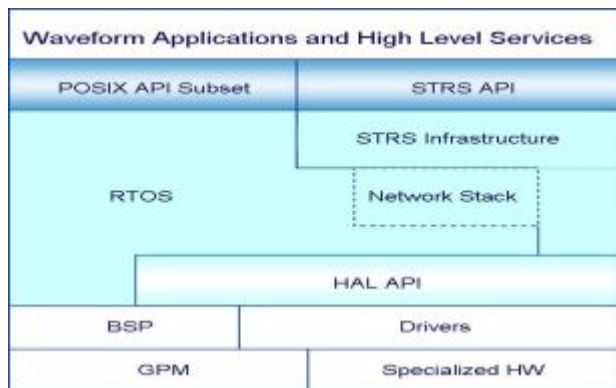
Radio Introduction

- Assess development cost and risk for space SDRs
 - Gain lessons learned for development, verifications, operations
 - Highlight routine on-orbit reconfigurability
- Infuse STRS into radio product lines
 - Assess development cost and risk for STRS compliance
 - Enable multiple providers of STRS radios
- Look to move more functions into the radio (e.g. framing traditionally done in flight computer)
- Leverage existing products to meet NASA needs
 - SDR (tech) developments used cooperative agreements to share cost/risk
- Capability driven by NASA needs, schedule, cost
 - Existing interfaces
 - S-band, Ka-band, GPS (L5)

SDRs are the core of the CONNECT Communication System

STRS SDRs

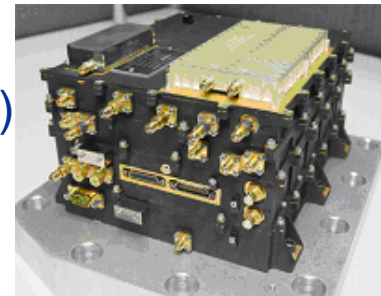
- Advance STRS/SDR Platforms to TRL-7
- Single standard on SDR and WF



- Compliance verified w/
 - tools
 - inspection
 - observation

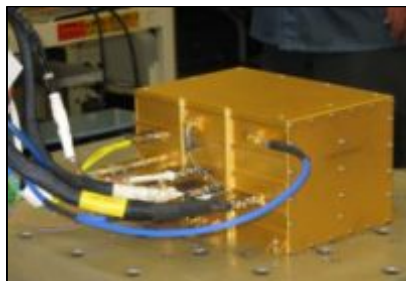
JPL/L-3 CE

- L-band receive (GPS)
- S-band SDR
- Tx: 2.2-2.3 GHz, 7W
- Rx: 2.025-2.12 GHz, (6 MHz channels)
- Virtex II, Sparc Processor (100 MIPS) , RTEMs OS, EDAC



General Dynamics

- S-band SDR
- Tx: 2.2-2.3 GHz, 8W
- Rx: 2.025-2.12 GHz (6MHz channels)
- Virtex II, ColdFire Processor (60 MIPS), VxWorks OS, CRAM (Chalcogenide RAM) Memory



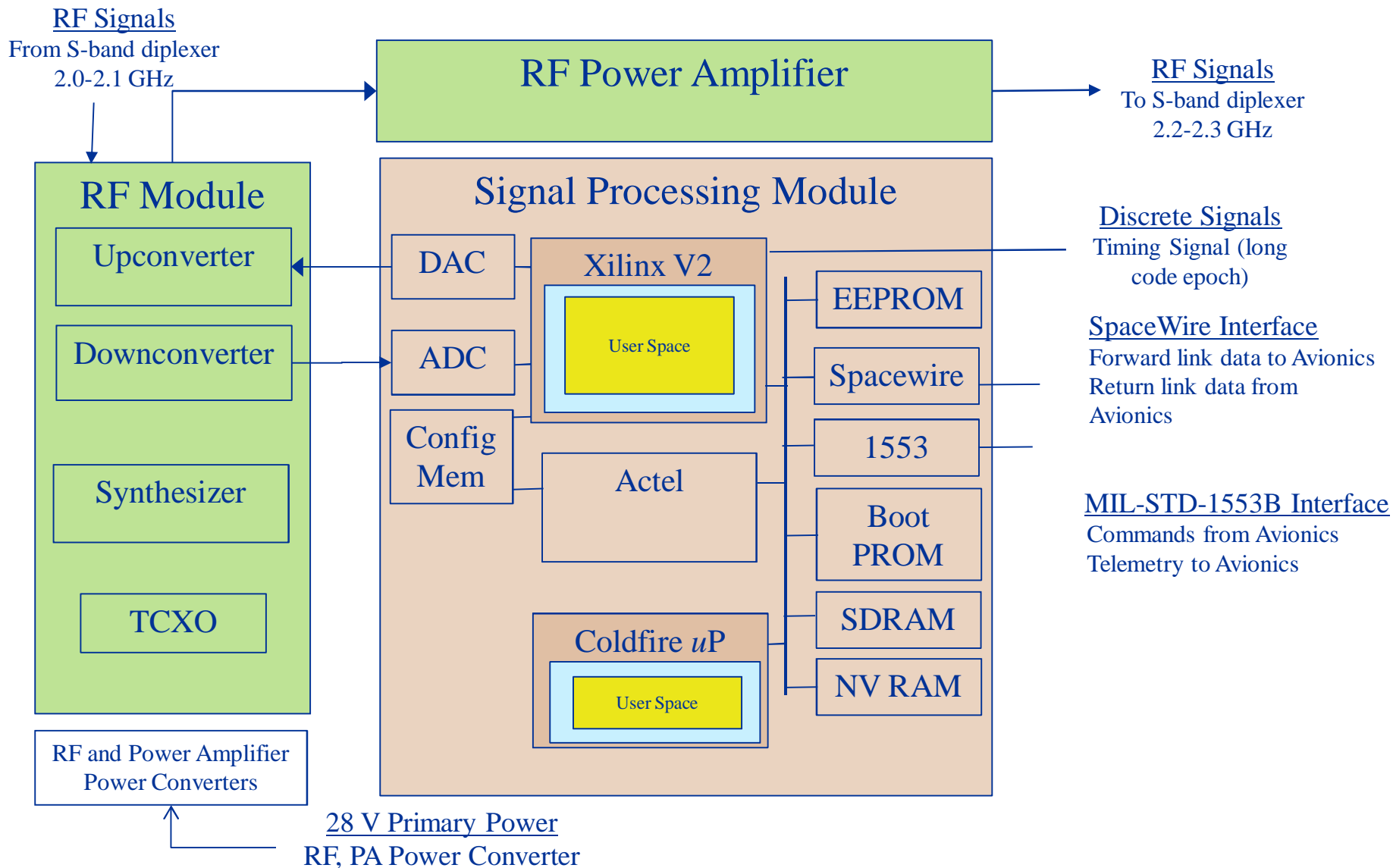
Harris

- Ka-band SDR
- Tx: 25.650 GHz, 225 MHz
- Rx: 22.680 GHz, 50 MHz
- Virtex IV, AiTech-PowerPC Processor (~700 MIPS), DSP (1 GFLOP), VxWorks OS, Scrubbing ASIC
- First Ka-band transceiver
- GSE – Avionics Comm/Telem Simulator



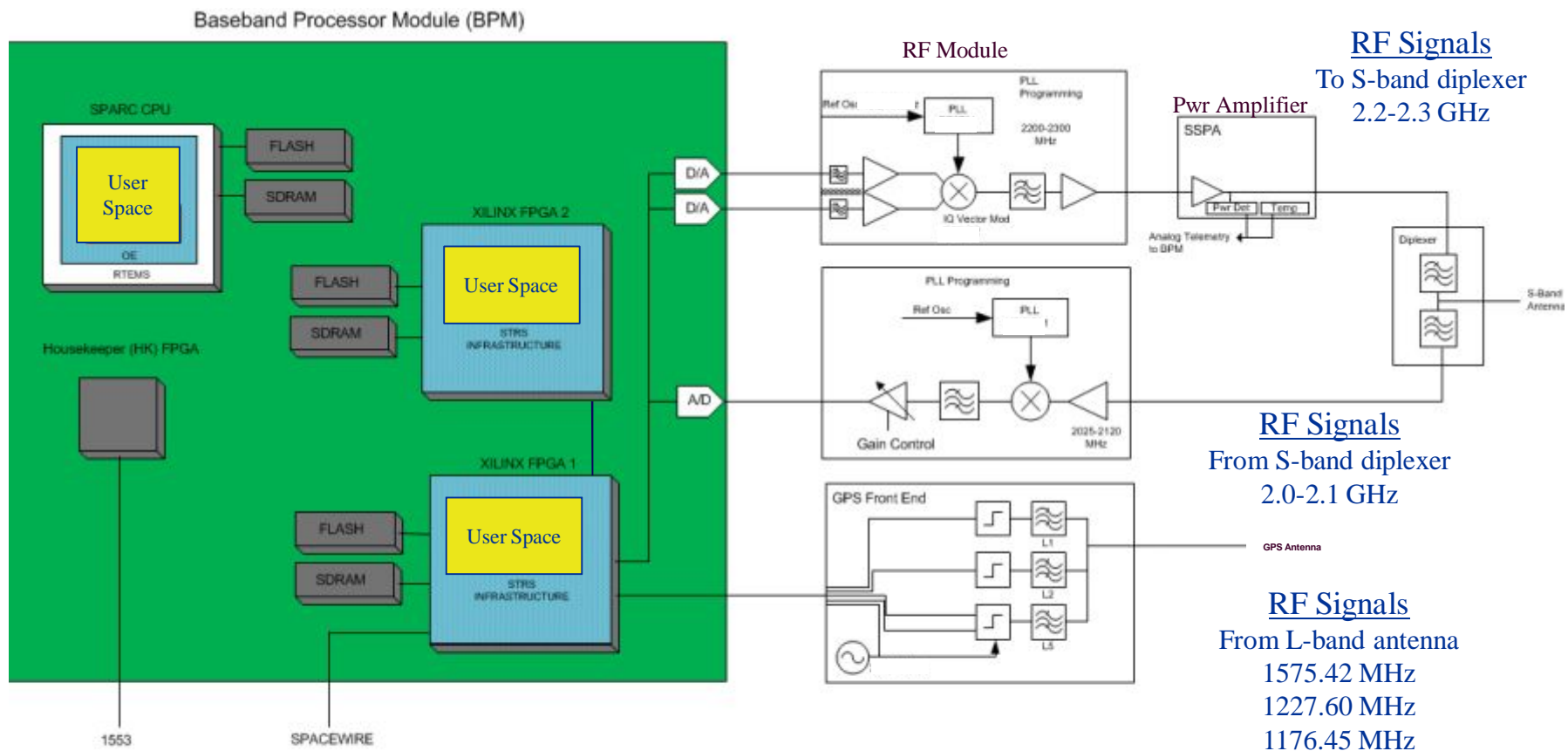


GD SDR Hardware Architecture





JPL SDR Hardware Architecture





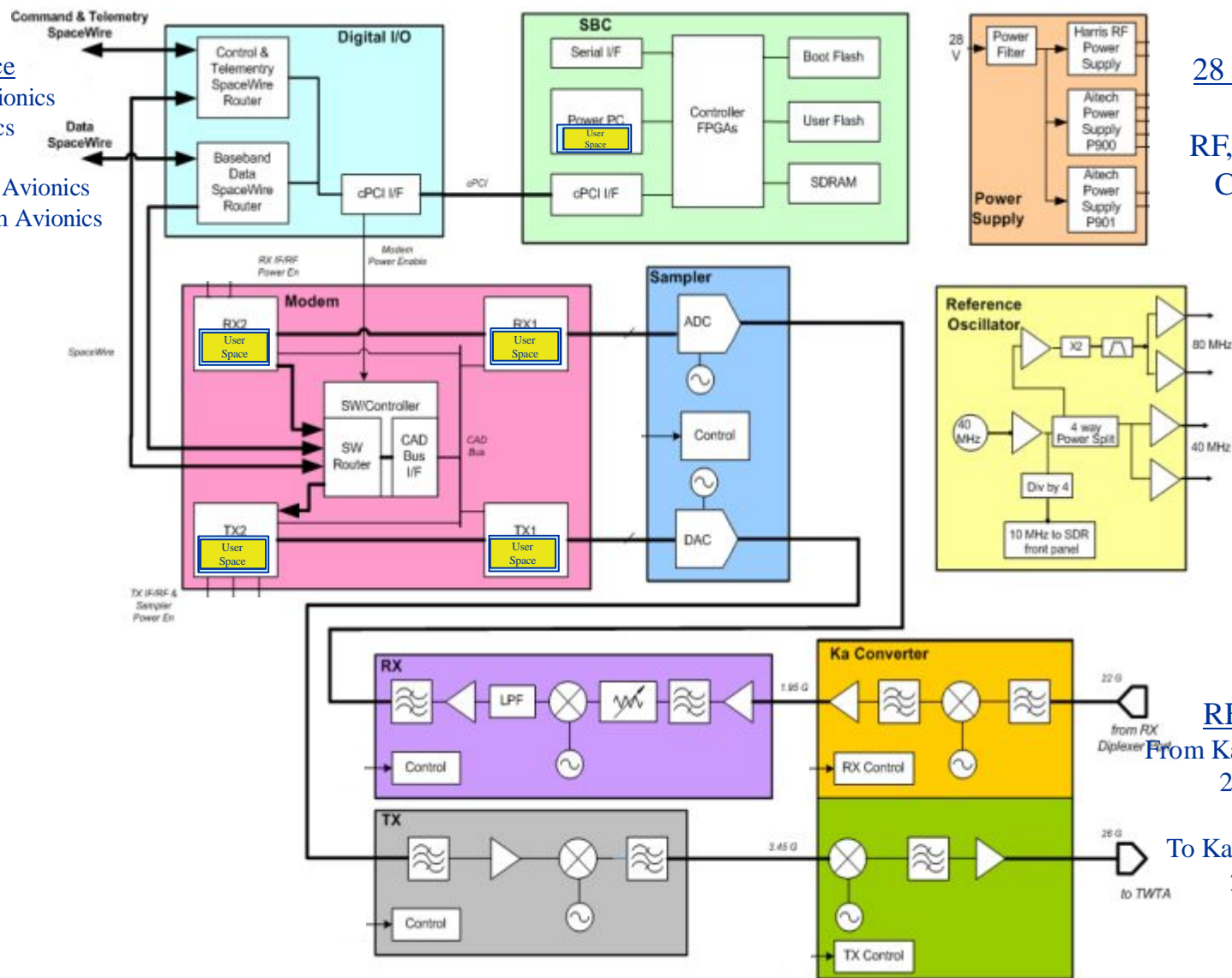
Harris SDR Hardware Architecture

SpaceWire Interface

Commands from Avionics
Telemetry to Avionics

Forward link data to Avionics

Return link data from Avionics



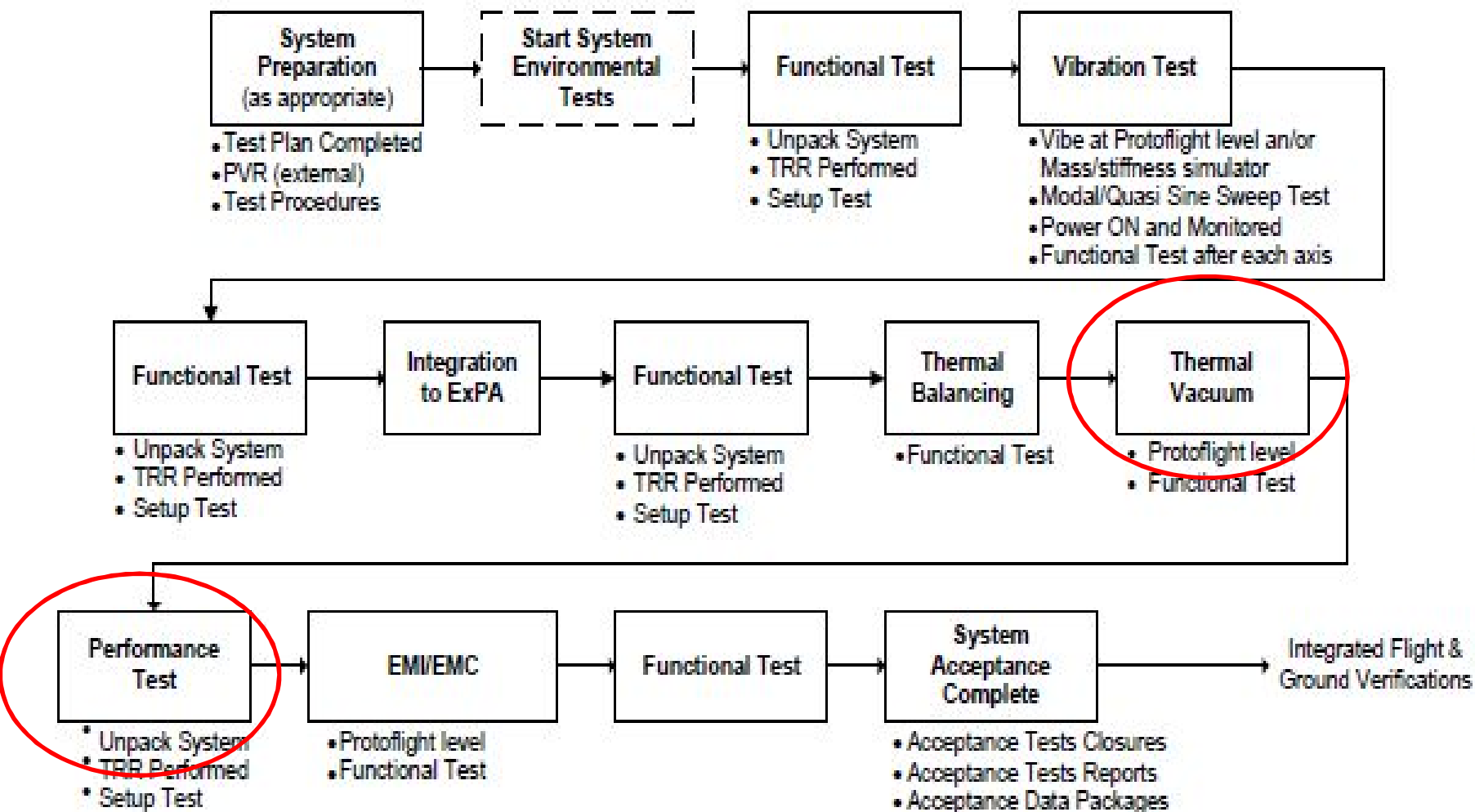
28 V Primary
Power
RF, PA Power
Converter

RF Signals
From Ka-band diplexer
22.0 GHz

To Ka-band TWTA
26 GHz



Environmental Verification / Validation Approach



SDR Communications System Tests mixed among Environmental Tests



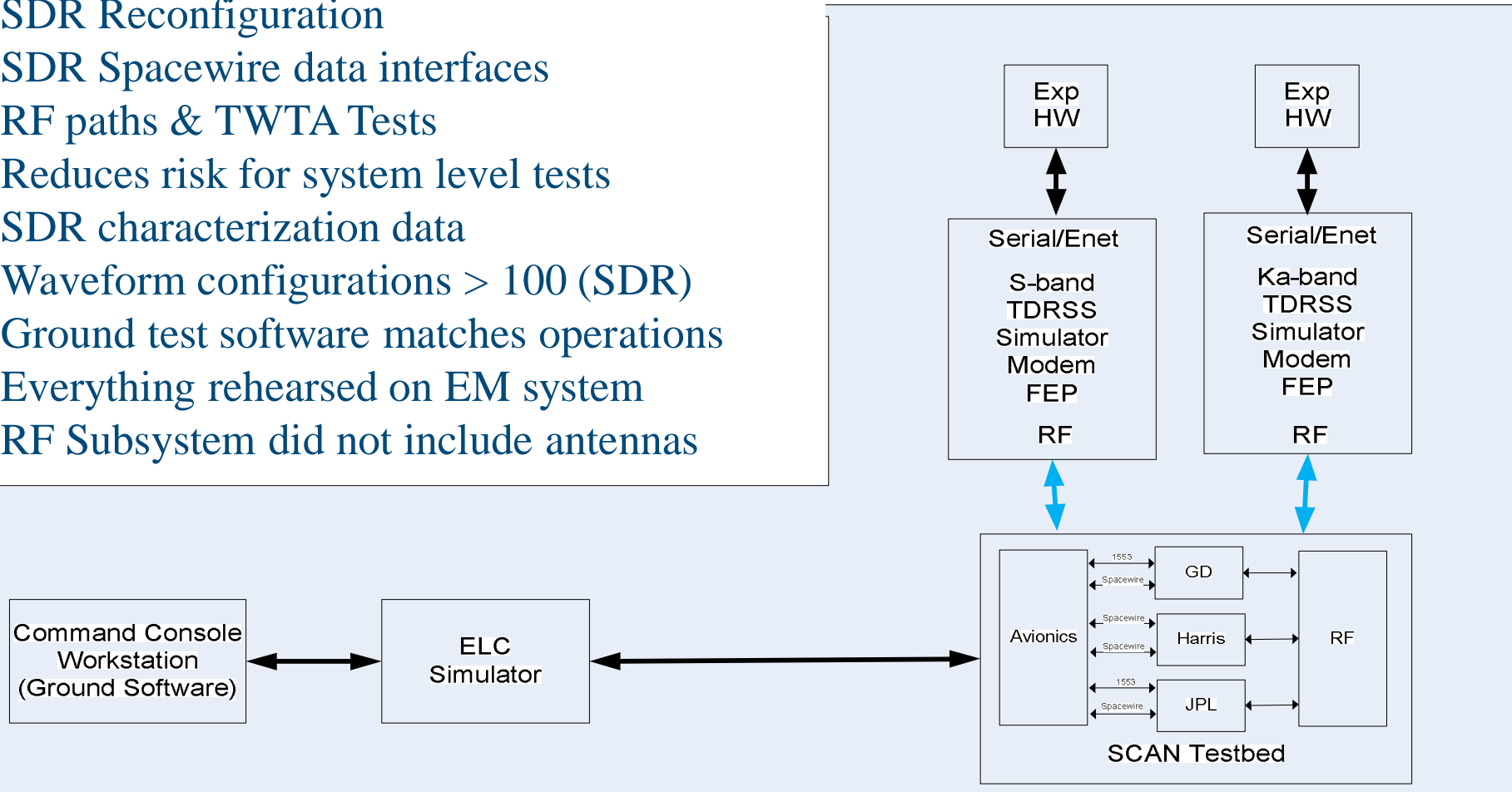
SDR Verifications: Thermal and Performance

- Plan tests for both application requirements & SDR characterization
- During platform development, require test waveforms for characterizations at system level (and box level)
 - IF interface on the SDR was helpful for JPL SDR system tests
- Thermal
 - Characterize platform aspects, especially when not able to characterize without waveform
 - Vector modulators in JPL SDR
 - Amplifier power (temperature compensating circuits)
 - Analog AGC, digital AGC, NF
 - Ka-band output (TWTA + SDR)
- Performance Test (SDR Applications (Waveforms) – Comm Functions)
 - Minimum Signal Level Tracking/Acquisition Threshold
 - Acquisition Time, False Lock susceptibility
 - Coded and Uncoded BER performance
 - Operating Frequency Control, Frequency Tracking Range
 - Transmitter Output Spectrum/Spectral Mask
 - Carrier Suppression
 - Characterized path from each antenna port to the radio
 - Performance in presence of interfering carriers and other PN codes

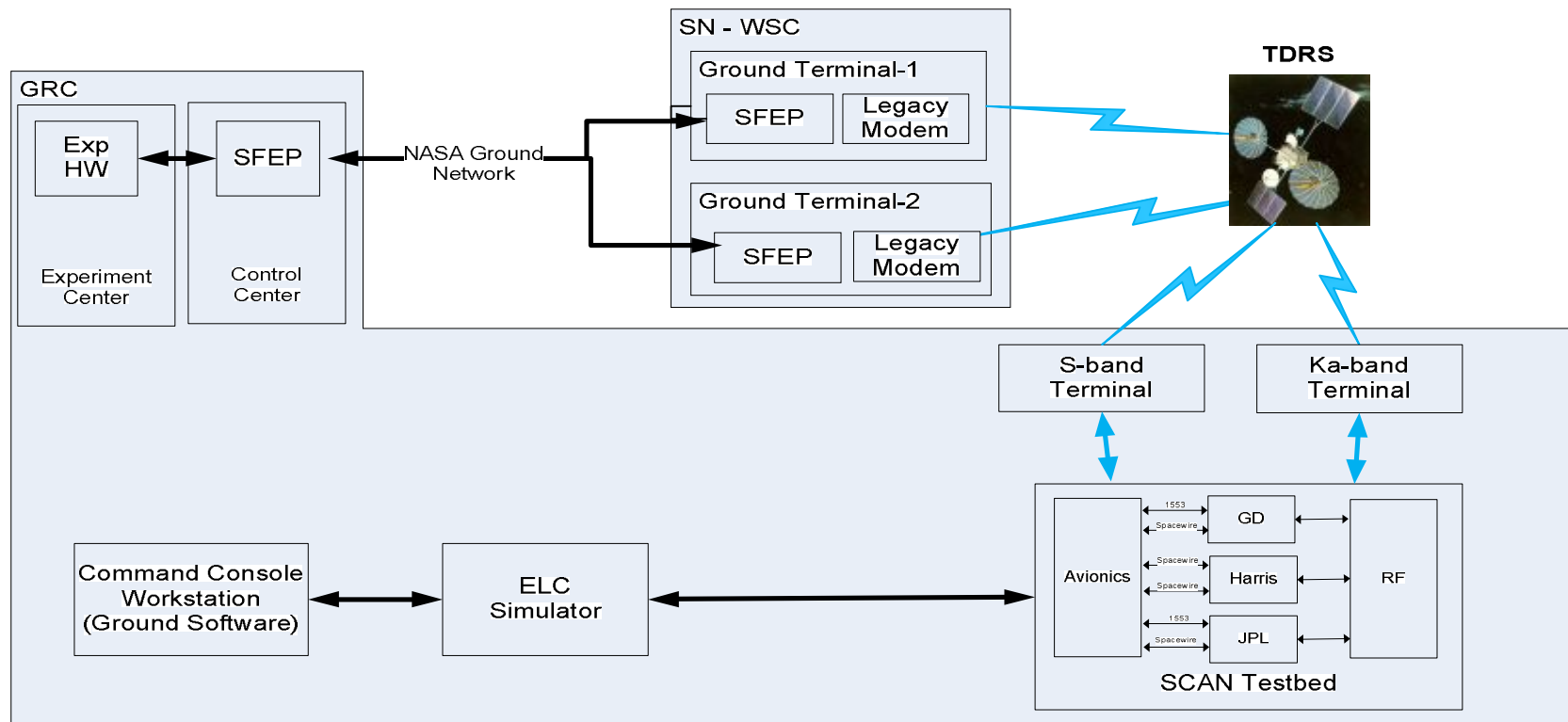


SDR & Communication System Test

- Tests signaling, modulation, data formatting
- SDR Reconfiguration
- SDR Spacewire data interfaces
- RF paths & TWTA Tests
- Reduces risk for system level tests
- SDR characterization data
- Waveform configurations > 100 (SDR)
- Ground test software matches operations
- Everything rehearsed on EM system
- RF Subsystem did not include antennas

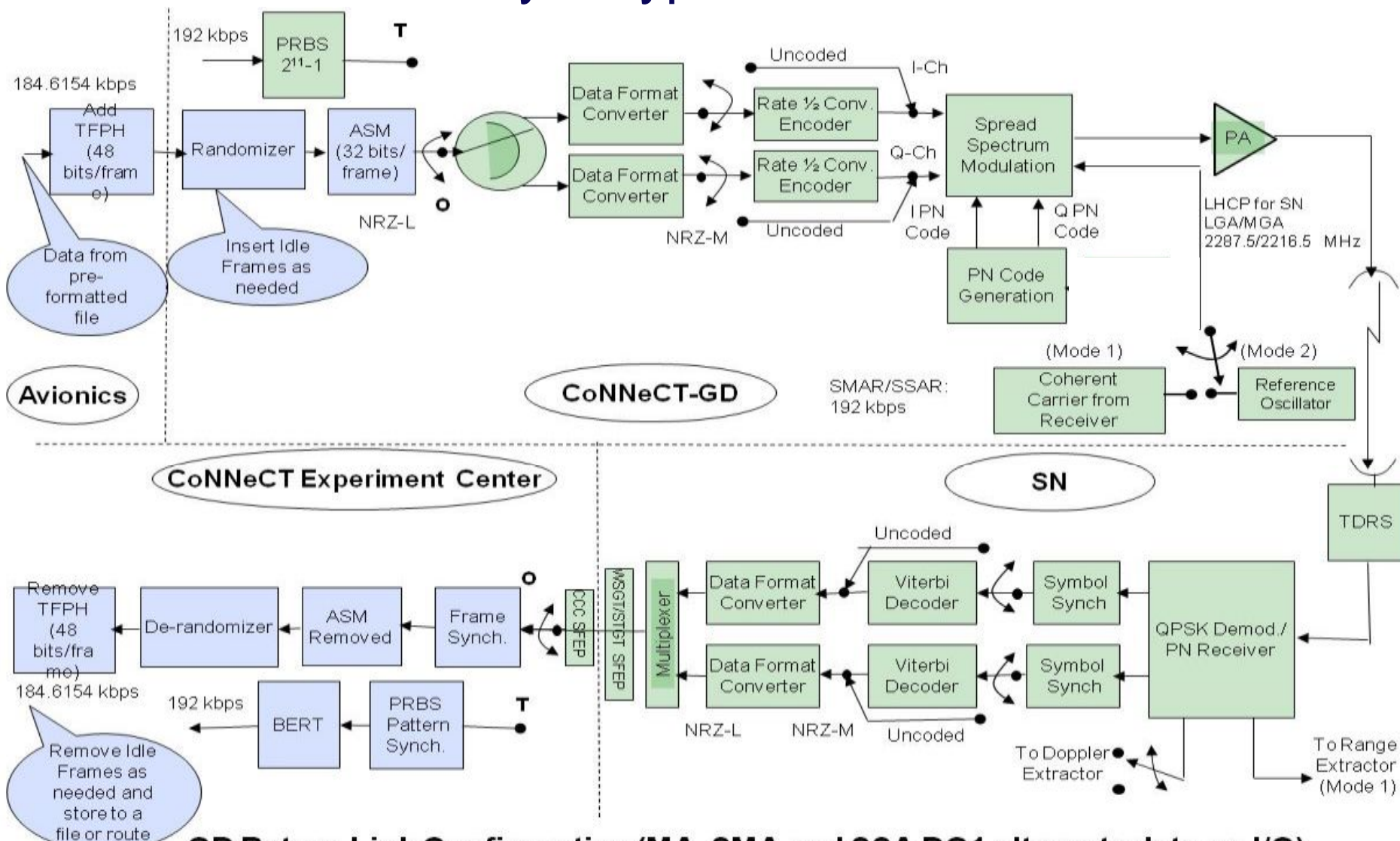


SN Compatibility Test, TDRSS Relay Link



- Demonstrates system in “test as you fly” configuration
- Uncovers incompatibility and configuration issues throughout the system
 - System configurations: 400-500 (SDR, FS antenna, SN)
- Pre-launch performance data
- RF Subsystem did not include antennas

Functionality of typical GD Return Link



GD Return Link Configuration (MA, SMA and SSA DG1 alternate data on I/Q)



SDR Verifications

- Identify early which SDR capability beyond mission requirements to include in requirements set
 - Amplifier characteristics (IF gain, I/Q balance to RF)
 - Temperature characteristics (digital and RF)
 - Trade verifications of essential mission requirements, while characterizing overall performance
- Manage Complexity!
 - Reconfigurable options (coding, framing, data rate, frequency) + mission configurations (payload antenna paths, TDRSS services) == 100's of configurations to manage.
- Changing the culture of verifications for space
 - Unable to test everything on ground before flight
 - Testbed designed to fly new flight configurations with verifications on ground hw only



SDR Development & Verification Conclusions

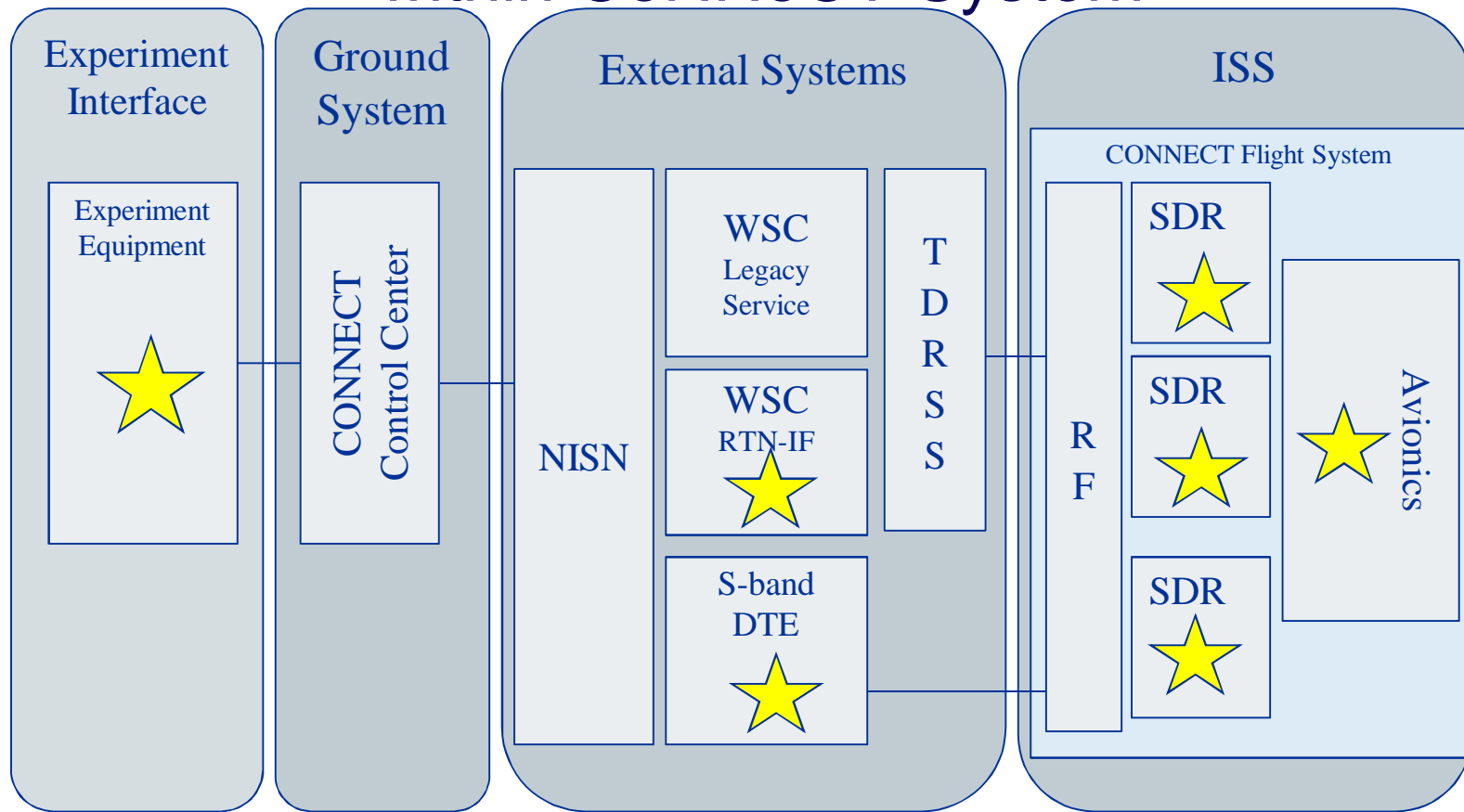
- SDR Development & Verifications
 - Spend systems engineering time on the SDR itself to separate platform and waveform aspects
 - Provide both platform and waveform requirements
 - Balance mission requirements with potential SDR reprogrammability capability
 - Understand platform performance for future waveform developers
 - Good documentation set
 - Divide test plan between platform and applications (Testbed requirements did not address full capability of radio, but rather concentrated on link functions)
- Experiment Opportunity for Academia and Industry
 - Develop/test applications and concepts– expect experiment call in mid 2012
 - Comm waveform development and operation in space
 - SDR-based mission concepts of operations
 - Networking experiments using avionics as router between SDR nodes
 - GPS-based navigation waveforms
 - Prove out STRS among multiple SDRs in space environment
 - Scheduled for launch in mid 2012



Backup



Experimenter Access Points within CoNNeCT System



★ = Experiment Element (e.g. sw, fw, hw, component)

Experimenters have access to
Flt SDRs, avionics, Gnd SDR, various ground points

SCAN Testbed Flight System Configuration

